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EASTERN LAKE SUPERIOR CHEMICAL AND PHYSICAL  
CHARACTERISTICS DATA FOR 1968

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# EASTERN LAKE SUPERIOR CHEMICAL AND PHYSICAL CHARACTERISTICS DATA FOR 1968\*

Gerald L. Bell

Water samples at standard depths, bottom sediment and meteorological data were collected in Eastern Lake Superior at established stations in the course of seven lake cruises and four St. Marys River cruises during the 1968 open-water season. The sampling program and analytical methods are described. Chemical characteristics of the water and bottom sediment are listed by cruise for each station and sampling depth. Wind, wave, and sediment data are listed by cruise for each station. The statistical summaries showing lake-wide means, standard deviations and sample sizes of selected variables are presented by depth for each cruise period.

## 1. INTRODUCTION

This basic data report presents data collected aboard the Research Vessel *Shenelon* by the Water Characteristics Branch of the Great Lakes Research Center, U.S. Army Corps of Engineers, Lake Survey District, between 28 May and 8 November 1968.

Data was collected systematically so that the vertical and lateral distribution of the chemical and physical characteristics of water in Lake Superior, as well as their variations with respect to time, were measured and examined. The sampling program was designed to provide the basic data that, together with other available data, are necessary for defining relationships of significant water characteristics, determining the rate and extent of mixing of introduced contaminants, forecasting water quality, estimating the nature and magnitude of past events, and developing simulation models for use in management and development of the lake (Great Lakes Research Center, 1969).

Interpretations of the data are not within the scope of this report and will be presented in subsequent publications. Meteorological conditions, as well as profiles of water temperature and transparency recorded at each station, are not included in this report. One report on these data is available (Adams and Kregear, 1969).

## 2. METHODS

### 2.1 Sampling Program

Water characteristics, bottom sediment, and meteorological data were collected at 72 established stations (Figure 1, Table 1). Stations 71 and 72 are at the same locations as stations 2 and 1, respectively, and are

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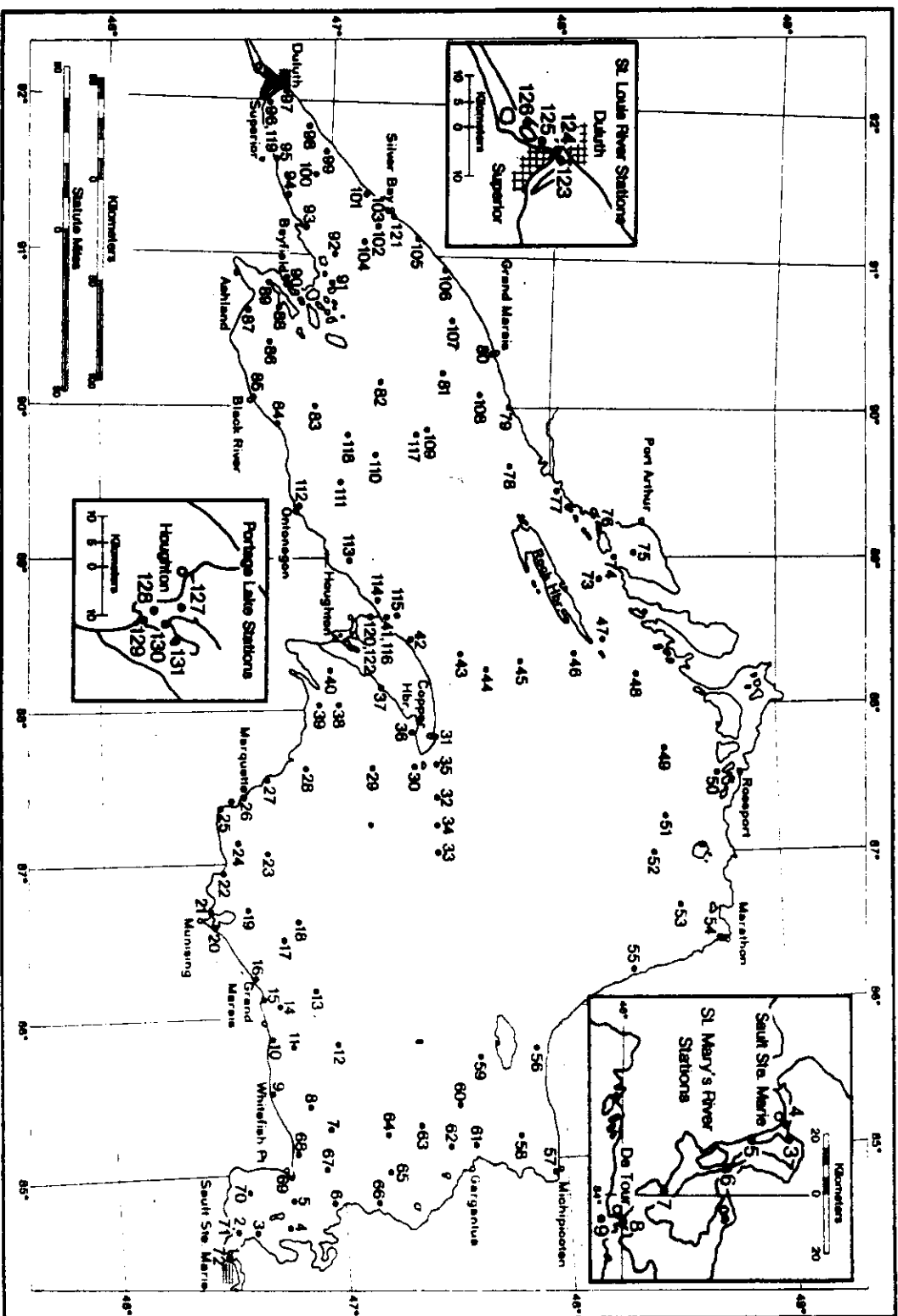


Figure 1. Station locations in Eastern Lake Superior (1-72) and the St. Marys River during 1968 and in Western Lake Superior (41-47, 73-119), the St. Louis River, and Portage Lake during 1969.

Table 1. Station Locations in Eastern Lake Superior and the St. Marys River During 1968 (by Latitude and Longitude)

Station	Latitude	Longitude	Station	Latitude	Longitude
1	46.47°N	84.46°W	37	47.22°N	88.13°W
2	46.51°N	84.62°W	38	47.06°N	88.02°W
3	46.60°W	84.60°W	39	46.97°N	88.02°W
4	46.75°N	84.63°W	40	47.02°N	88.25°W
5	46.77°N	84.80°W	41	47.27°N	88.60°W
6	46.95°N	84.77°W	42	47.37°N	88.45°W
7	46.95°N	84.25°W	43	47.60°N	88.35°W
8	46.87°N	83.40°W	44	47.72°N	88.25°W
9	45.70°N	83.50°W	45	47.87°N	88.30°W
10	46.71°N	85.85°W	46	48.10°N	88.35°W
11	46.80°N	85.80°W	47	48.23°N	88.45°W
12	47.00°N	85.80°W	48	48.38°N	88.20°W
13	46.92°N	86.15°W	49	48.50°N	87.70°W
14	46.75°N	86.05°W	50	48.73°N	87.53°W
15	46.68°N	86.10°W	51	48.50°N	87.25°W
16	46.65°N	86.25°W	52	48.45°N	87.00°W
17	46.78°N	86.49°W	53	48.55°N	86.65°W
18	46.85°N	86.60°W	54	48.72°N	86.42°W
19	46.63°N	86.70°W	55	48.33°N	86.22°W
20	46.48°N	86.59°W	56	47.87°N	85.72°W
21	46.45°N	86.69°W	57	47.94°N	84.90°W
22	46.53°N	86.95°W	58	47.80°N	85.15°W
23	46.73°N	87.05°W	59	47.63°N	85.68°W
24	46.60°N	87.12°W	60	47.53°N	85.37°W
25	46.52°N	87.35°W	61	47.59°N	85.10°W
26	46.63°N	87.43°W	62	47.48°N	85.10°W
27	46.73°N	87.53°W	63	47.35°N	85.25°W
28	46.91°N	87.60°W	64	47.20°N	85.20°W
29	47.20°N	87.60°W	65	47.20°N	84.95°W
30	47.38°N	87.60°W	66	47.15°N	84.75°W
31	47.48°N	87.80°W	67	46.92°N	85.00°W
32	47.48°N	87.40°W	68	46.80°N	85.10°W
33	47.48°N	87.04°W	69	46.77°N	84.95°W
34	47.48°N	87.22°W	70	46.58°N	84.88°W
35	47.48°N	87.62°W	71	46.51°N	84.62°W
36	47.37°N	87.83°W	72	46.47°N	84.46°W
<u>St. Marys River</u>					
3	46.51°N	84.24°W	7	46.13°N	84.02°W
4	46.49°N	84.31°W	8	46.00°N	83.89°W
5	46.39°N	84.24°W	9	45.94°N	83.89°W
6	46.32°N	84.12°W			

used to identify data obtained by resampling at the end of the cruises. Sixty-three stations were in the eastern basin, while the other nine were in Whitefish Bay and the upper St. Marys River. Seven stations (3-9) in the St. Marys River between the lock and Lake Huron were also sampled (Inset, Figure 1). Seven cruises in the lake and four in the River were made during the survey season (Table 2). A cruise is defined as the time period starting when the *Shenelon* left Sault Ste. Marie, Mich., and ending upon the return to the same port. A full cruise normally required 2.5 weeks. Shipboard and laboratory determinations made during each cruise are summarized in Table 3.

The ship was navigated and stations were established by using a gyro compass, radar, a sextant, and visual fixes. Polystyrene floats were used to mark the deep-water stations and to facilitate the return to the same location. Water sample depths in feet were determined by a meter wheel and converted to the nearest meter. The water depth to the bottom was determined by a Raytheon Precision Survey Fathometer, Model DE-723B, with a range of 0 to 250 in feet or fathoms and the depth presented as a graphic record on a calibrated paper chart.

Water samples were taken at multiple levels at each station in Fjarlie bottles. Samples from stations located in shallow water were sampled at the surface, mid-depth, and near bottom. In the upper 100 m, samples from stations located in deep water were taken at the surface and spaced at 10-, 20-, or 25-m intervals. Below 100 m, the spacing was 50- to 100-m intervals, with the deepest sample near bottom. Bottom sediment samples were taken with a Shipek Sampler.

Water temperatures were recorded at sampling depth to the nearest hundredth degree Celsius by protected reversing thermometers ( $\pm 0.02^\circ$  accuracy) attached to each Fjarlie bottle. The temperature of the water circulating through the sea chest, approximately 1.5 m below the surface, was recorded to the nearest tenth degree Celsius and printed with the meteorological data at 6-min intervals. Temperature profiles were recorded at each station to a maximum depth of 80 m with a Marine Advisors, Inc., Electronic Bathythermograph, Model 0-5a. The bathythermograph profiles were corrected by adding or subtracting the average difference between the reversing thermometer and bathythermograph temperatures.

Transparency profiles were made to a maximum of 80 m with a G.M. Mfg. and Instrument Corp. Deep-Water Turbidity Meter, Model 17-M-11, modified by the U.S. Lake Survey. Transparency was determined by relating light transmission along a 1-m path through the water to the transmission along the same path through air, expressed as a percent. Color filters were not used.

Meteorological observations were recorded automatically at 0.1-hr intervals by a digital system employing solid state data gathering modules. Wind and wave observations were made while on station. The

Table 2. Cruise Schedule

Cruise	Date
1	28 May-17 June
2	22 June-12 July
3	18 July-9 Aug.
4	16 Aug.-31 Aug.
5	4 Sept.-25 Sept.
6	2 Oct.-26 Oct.
7	1 Nov.-8 Nov. (partial cruise)
<u>St. Marys River</u>	
5	26 Sept.
6	27 Sept.
7	30 Oct.
8	31 Oct.

wave direction was not reported at all stations and in such cases the wind direction was used. Wave height observations were made with a damped staff-type gage or by estimating and periodically checking with the gage. The period is based on an average time of 10 successive waves.

## 2.2 Chemical Analyses

The methods used in the water analysis are those described in Standard Methods (American Public Health Association, 1965), Rainwater and Thatcher (1960) and Fishman and Skougstad (1965).

Water samples were analyzed immediately in the *Shenehon* laboratory for dissolved oxygen, specific conductance, chloride, phenolphthalein and total alkalinity, pH, Eh (oxidation-reduction potential), the pH and Eh of the interstitial water of the bottom sediment, and total coliforms.

Dissolved oxygen values were determined with a Beckman Dissolved Oxygen Analyzer, Model 777. After two separate tests were made on each sample, the highest partial pressure and the lowest sample temperature readings were used for calculating the dissolved oxygen. *In situ* temperature was recorded by the reversing thermometer at the sampling depth.

*Table 3. Shipboard and Laboratory Measurements in Connection with Limnological Studies*

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Shipboard Measurements

Meteorological data (printout each 6 min)

Wind speed (m/sec) (10 m above water)  
 Wind direction (10 m above water)  
 Barometric pressure (millibars) (3 m above water)  
 Air temperature (°C) (10 m above water)  
 Water temperature (1.5 m below water surface)  
 Solar radiation (incident) (gram-calories per sq. cm), (10 m above water)  
 Relative humidity (3 m above water)

On station

Water

Water temperature (°C)  
 Reversing thermometers at sample depth  
 Electronic bathythermograph  
 Infrared thermometer for surface temperature  
 Air-water interface temperatures  
 Transparency (relative to 100% in air)  
 Secchi disc (m)  
 pH  
 Eh (volts)  
 Total and phenolphthalein alkalinity (mg/l CaCO<sub>3</sub>)  
 Chloride (mg/l)  
 Specific conductance (micromhos at 25°C)  
 Dissolved oxygen (mg/l and pct. sat.)  
 Coliform bacteria (membrane filter proc.)

Waves

Height (m)  
 Period (sec)  
 Direction (nearest 10°)

Bottom sediment

Description (physical)  
 pH  
 Eh  
 Biochemical oxygen demand

Chemistry Laboratory

Dissolved ions (Beckman DU-2 Spectrophotometer)

Nitrate	(Brucine method, A.P.H.A.*, 1965)
Phosphate	(Ammonium Molybdate method, U.S.G.S.**, 1965)
Sulfate	(Turbidimetric method, A.P.H.A.*, 1965)
Silica	(Molybdate blue method, U.S.G.S.**, 1960)
Magnesium	(Eriochrome black T method, U.S.G.S.**, 1960)
Calcium	(Flame photo tech, A.P.H.A.*, 1965)
Sodium	(Flame photo tech, A.P.H.A.*, 1965)
Potassium	(Flame photo tech, A.P.H.A.*, 1965)

Suspended sediment (mg/l)

Bottom sediment

Percent solids  
 Percent volatiles  
 Oil and grease  
 Macrofauna

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\*American Public Health Association.

\*\*U.S. Geological Survey.

Specific conductance was measured with an Industrial Instruments Conductivity Bridge, Model RC-16B2J. Two separate tests were made on each sample and the average expressed in micromhos at 25°C.

Chloride concentrations were determined by the argentometric method and titration of a 50-ml sample of lake water. The silver nitrate was standardized and the reagent blank value determined at the beginning of each day.

Phenolphthalein and total alkalinity values were determined by titrating 100-ml water samples with standard acid ( $H_2SO_4$ ) to the end-points of pH 8.2 and 4.5, respectively. The end-points were determined with the pH meter and the results expressed in mg/l of calcium carbonate.

Measurements of pH and Eh were made with a Beckman Zeromatic pH meter, a glass pH electrode, calomel fiber junction reference electrode, and a platinum Eh electrode. As a means of avoiding contamination, the electrodes were rinsed in a sample of the lake water to be tested. Between tests, the electrodes were immersed in distilled water. Tests of the interstitial water of the bottom sediment were made by inserting the electrodes into the soft sample.

Unpreserved water samples in 500-ml plastic bottles were stored in a dark area below deck and transferred at the end of each cruise to the Great Lakes Research Center laboratory in Detroit for additional testing. Tests for nitrate and phosphate were made on unfiltered samples upon arrival at the laboratory. A Beckman DU-2 Spectrophotometer with flame attachment was used to analyze samples. Standard Curves were constructed for each test and cruise. Sample concentrations were determined by computer application of the absorbency values to a standard curve that was adjusted by paired test standards run after each set of 10 to 20 samples in order to compensate for any change or drift in the spectrophotometer response.

The bottom sediment was dried overnight at 100-105°C and the weight expressed as a percentage of the wet weight. Volatiles were determined by burning at 600°C for 1 hr and reported as a percentage of the dry solids. The concentration of hexane extractable hydrocarbons was determined by distillation and the weight reported as a percentage of the dry solids. The biochemical oxygen demand tests were generally made on 1 gram of sediment incubated at 20°C.

### 3. PRECISION LIMITS

The degrees of precision of the various tests are summarized in Table 4. The estimated precision of the dissolved oxygen determination is based on the assumption that the oxygen partial pressure is accurate to 1 mm of mercury. The average difference in the two partial pressure readings for each sample was less than 1 mm of mercury. For specific

Table 4. Measurement Precision

Variable	Units	Estimated precision	Average deviation*
Dissolved oxygen.	percent	±1.0	
	mg/l	±0.1	
Specific conductance	micromhos at 25°C	±1.0	
Chloride	mg/l	±0.5	
Alkalinity	mg/l	±0.5	
Nitrate-N**	mg/l	±0.02	
Phosphate-P**	mg/l		±0.0003
Sulfate	mg/l		±0.29
Silica	mg/l		±0.06
Calcium	mg/l		±0.19
Magnesium	mg/l		±0.06
Sodium	mg/l		±0.09
Potassium	mg/l		±0.03

\*Average of the deviations of the test standards from the standard curve.

\*\*Analysis of unfiltered samples of uncertain storage history.

conductance, the estimated precision is based on the assumption that the average difference in the two conductance readings for each sample is less than 1 micromho. For both chloride and alkalinity, the estimated precision is based on the value of one drop (0.05 ml) of titrant and on the estimation that the accuracy was within  $\pm$  one drop.

In order to determine the repeatability of the tests with the spectrophotometer, one must compare the pairs of test standards to the standard curve for that ion. Table 4 shows the average deviation of these standards from the best-fit curve. The precision for nitrate-nitrogen was estimated because single standards were run to correct for machine drift.

From the end of a cruise to the date of analysis, there was an interval ranging from 1 to 5 weeks for phosphate and from 1 to 7 weeks for nitrogen. These samples were not preserved to fix the phosphorus and nitrogen, nor were they refrigerated. Therefore, possible deterioration must be a consideration when using these values.

#### 4. DATA PRESENTATION

The limnological data are summarized by cruise for each sampling depth at a given station (Appendix A). Phosphorus concentrations were calculated from phosphate by multiplying by a factor of 0.326.

The wind, wave, and bottom sediment data, with the exception of pH and Eh, are summarized by cruise and station (Appendix B).

In the statistical summary, lake-wide means, standard deviations, and sample sizes are presented (Appendix C) by depth and cruise period for selected variables.

#### 5. ACKNOWLEDGMENTS

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